SEMIANNUAL PROGRESS REPORT

on

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Under NASA Research Grant No. NsG 110-61, research to establish methods of structural synthesis has been underway since December 1, 1960 at Case Institute of Technology.

During this report period work continued on four synthesis projects.

1. Extension of the Shock Isolator Study.

An extension of the previously reported (Ref. 1) synthesis capability for a simple shock isolator has been completed and reported in Ref. 2. Advances in the engineering scope and the algorithmic efficiency of the previous work are presented. A one-degree of freedom system with a single package of mass M is to be protected from a multiplicity of shock pulses. Two common situations are considered. In the first type of problem a design is sought which minimizes the absolute acceleration felt by the package subject to relative displacement limitations. In the second type of problem a design is sought which minimizes the relative displacement subject to limitation on the absolute acceleration felt by the package. Three design variables are employed to characterize the bilinear spring and six additional design variables are used to represent a piecewise linear variable damping coefficient. The synthesis technique employed is based on an implementation of the gradient projection method, with certain special additional features. Results for several numerical examples are presented in Ref. 2. By permitting a broader class of possible designs it was found that a reduction of as much as 25% in the criterion function value, at termination of the synthesis, could be obtained in some cases.

2. Integrated Approach to Structural Synthesis and Analysis.

An integrated approach to structural synthesis and analysis was first reported in Ref. 3 which has since been published as Ref. 4. Both the structural scope and algorithmic efficiency have been substantially advanced during the past year.

An integrated analysis-synthesis capability for a general three dimensional truss of arbitrary preassigned topology has been reported in Ref. 5. The design variables are the mean diameter and thickness of each tubular member. Two distinct programs exist with the following characteristics:

A. Mixed force displacement type analysis formulation, option to use Ramberg-Osgood stress strain relation and base member buckling and crippling on tangent modulus.

B. Displacement type linear analysis formulation, option to link design variables, variable metric minimization.

The increased efficiency achieved by adopting the minimization algorithm of Ref. 6 was substantial (approximately a factor 3 times faster). However, this method requires the storage of a large matrix which limits the size of problems that can be handled without resorting to auxiliary storage. Continuing effort on the integrated approach will be aimed at further improvement in the efficiency and modification of the program so that the current storage limitations will be alleviated.

3. Materials Evaluation Function Study

The materials evaluation function (MEF) is essentially a function relating material merit in a particular application, with the properties

that characterize the material in the application. The basic idea has been explored using the three bar truss as a representative application with the density, yield stress, and modulus of elasticity as characteristic material properties. The results of this preliminary study were good and it has been decided to pursue the generation of an MEF based upon a structural task more representative of aerospace practice.

The system for which a structural synthesis problem statement is being formulated is a simply supported rectangular panel which will be viewed as part of the outer shell of a re-entry vehicle. The panel is composed of three layers. The outer layer is an ablating heat shield. This is attached to a structural layer, which is backed up by an insulating layer. The objective of the synthesis will be minimization of total weight. The design variables will be the layer thicknesses and the support spacings. Each load condition will be given by specifying a heat flux and dynamic pressure time history. Behavior functions are being devised to guard against excessive temperature (in the structural layer and at the back of the insulating layer), excessive panel deflection, excessive stress in the structural layer, as well as panel flutter and ablator spalling. Current effort on this study is primarily concerned with putting together a meaningful, yet tractable analysis, on which to base the synthesis capability. The synthesis capability will then be available for use in generating data points from which to construct materials evaluation functions based on this representative application.

4. Structural Synthesis applied to Stiffened Cylindrical Shells.

The application of structural synthesis methods to the minimum weight design of different types of cylindrical shell construction based

upon recommended analyses employed in aerospace practice has been initiated. Extensive study of the literature and consultations with Langley Field have been carried on during this report period. It is anticipated that an analysis base, representative of current practice, will be agreed upon during the forthcoming report period. It is intended that this study include various types of shell construction such as:

(a) ring and stringer stiffened (inside and out)

(b) integrally stiffened (with and without rings)

(c) sandwich (with and without rings)

This study will include multiple load conditions in which each load condition may contain combined loadings such as axial load, pressure, and bending. It is intended that the sensitivity of the optimum design to changes in load conditions and various preassigned parameters be assessed.

During the next report period two new projects will be initiated, one of these is a comparative evaluation of synthesis techniques and the other will be an investigation of the impact of nonlinear structural analysis on structural synthesis.

REFERENCES

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